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(54) Spin-valve dual magnetoresistive reproduce head

Magnetoresistiver Wiedergabekopf mit doppeltem Spin-Ventilelement

Tête de reproduction magnétorésistive à spin-valve duale

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EP-A- 0 490 608	EP-A- 0 539 213
WO-A-91/15012	US-A- 5 159 513
US-A- 5 287 238	US-A- 5 301 079

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Description

[0001] This invention relates to a magnetic reproduce head, and in particular to a magnetoresistive reproduce head.

[0002] As magnetic recording technology continues to push areal recording density limits, magnetoresistive (MR) reproduce heads appear to be the technology of choice. Recent US-A-5,084,794 and US-A-5,193,038 disclose dual magnetoresistive (DMR) reproduce heads which offer improved high linear density performance compared to conventional shielded magnetoresistive (SMR) heads, as well more robust operation and simpler fabrication. Until very recently, virtually all past magnetoresistive sensor/heads, including the DMR design, have been based on the physical phenomenon of anisotropic magnetoresistance (AMR) in Permalloy (NiFe) thin films. US-A-5 159 513 discloses a magnetoresistive sensor employing the relatively recently discovered "spin-valve" (SV) effect, which is fundamentally distinct from the AMR effect. Sensors or heads based on spin-valve technology can potentially yield significantly greater intrinsic sensitivity and signal levels than any design of conventional the AMR-based sensor or head.

[0003] Ideally the basic SV sensing element is a tri-layer film of two thin-film magnetic layers sandwiching a very thin non- magnetic conductor. Referring to Figs. 1a, 1b the basic SV sensor of the prior art consists of the two magnetic layers 10, 12 of thicknesses t_1 and t_2 respectively, separated by a nonmagnetic conductive spacer 14 of thickness t_g, all deposited on a substrate 11. It is to be noted that this SVMR sandwich of magnetic layers 10, 12 and spacer 14 corresponds to the single magnetoresistive film of the prior art AMR sensor. In general, the individual magnetic layers 10, 12 may be either single or multiple layers generally of Co, Fe, and/or Ni; the conductive spacer is generally Au, Ag or Cu. Due to the "spin-valve" effect, the resistivity ρ of the SV trilayer has a component which depends upon the cosine of the angle between magnetization vectors M_1 and M_2 in the films 10, 12, as will be described below. Depending upon film composition, SV trilayers have been observed to have a magnetoresistive coefficient $\Delta\rho/\rho_0$ as large as 8%. This is nearly four times larger than typically found for traditional AMR in NiFe, which accounts for the current substantial interest in SV technology for magnetic recording heads.

[0004] The sensor geometry of Figs. 1a, 1b is designed for detecting magnetic fields H_s along the direction transverse to the SV stripe. Such fields will rotate the magnetization directions, that is, M_1, M_2 in either magnetic film 10, 12, thereby inducing a change in the magnetoresistive component of ρ. This in turn changes the net electrical resistance of the SV stripe, creating a voltage change across the terminals of the SV sensor when a constant sense current is passing through the device. In general, the magnetoresistive component of ρ varies as $\Delta\rho \cos(\theta_1-\theta_2)$, where θ_1 is the angle between the magnetization M_1 and the longitudinal direction of the film 10, and θ_2 is the angle between the magnetization M_2 and the longitudinal direction of the film 12. Therefore, it is necessary that the films 10 and 12 respond differently to signal fields such that the difference $\theta_1-\theta_2$ will vary with the field.

[0005] For the SV head as disclosed in US-A-5,159,513, the magnetization M_2 is "pinned" at $|\theta_2|=90°$, and resultantly the magnetoresistive component of ρ varies as $\Delta\rho \sin\theta_1$. Due to magnetization rotation, $\sin\theta_1$ is proportional to the net transverse signal field H. If $\theta_1 \approx 0$ at the zero-field quiescent bias point of the SV sensor, the "sensor output" ∝ "change in $\sin\theta_1$" ∝ "change in $\sin\theta_1$" ∝ "signal field H", , and the SV responds linearly to the signal fields over the maximum possible dynamic range $-90° \leq \theta_1 \leq 90°$ prior to the saturation of the film 10. This illustrates why the perpendicular bias state $\theta_1 \approx 0°$ and $\theta_2 \approx 90°$ is the most desirable for practical application of the SV type magnetoresistive head.

[0006] In a practical SV sensor some means is required for pinning the direction of magnetization M_2 of the magnetic layer 12 so that it is substantially perpendicular to the quiescent magnetization M_1 of the magnetic layer 10, which is otherwise free to rotate in response to a magnetic signal field. The preferred means for stabilizing this perpendicular magnetization state as taught in US-A-5,159,513 entails two distinct features. Firstly, it requires that there be a thickness and/or composition mismatch between the two magnetic SV layers, and secondly, it involves an additional magnetic biasing layer, that is, the exchanged coupled biasing layer 16 of Figs. 1a, 1b.

[0007] Fig. 1b shows the cross section of the SV sensor of Fig. 1a, including deposited current leads 18,20.

[0008] In Fig. 2, a simplified schematic representation of the perpendicularly biased SV of US-A-5,159,513 illustrates some critical structural and related magnetic features inherent in the design. As taught in the referenced patent, films 10, 12 are Co based alloys and/or NiFe, pinning layer 16 is antiferromagnetic FeMn, and spacer 14 is Cu. The thicknesses of the films 10, 12, 16 and the spacer 12 are as follows: film 10; $t_1 \approx 7.5$nm, film 12; $t_2 \approx 3.5$nm, film 16; $t_3 \approx 10$nm, and spacer 12; $t_g \approx 3$nm. All elements are of height L in the transverse direction. Also diagrammed are the transverse magnetic fields present under bias conditions (excluding signal fields), including demagnetization fields H_d and current fields H_j arising from the current density J flowing in the device. There are several possible drawbacks to this design: viz,

a) The design requires a thickness or composition mismatch between the films 10 and 12, and this should be detrimental to the maximum achievable magnitude of $(\Delta\rho/\rho)$. This is because the basic spin-valve effect requires sharing of conduction electrons between the two magnetic layers (through the

Cu spacer), and this is done most equally and efficiently when the magnetic layers are nominally the same, that is, when the thicknesses of the films 10,12 are equal. In practice, there are several reasons why such a thickness mismatch may be unavoidable. Generally, $\theta_1 \propto (H_j+H_d)/t_1$, so that for θ_1 to be near 0°, it is necessary that t_1 be sufficiently large, and that at film 10 the demagnetization and the current fields approximately cancel. The direction of current flow J in Fig. 2 was deliberately chosen such that H_j is antiparallel to H_d at the site of film 10. However, $H_d \propto t_2/L$, while $H_j \propto J(t_2+t_g)$, and for the small element heights, $L \approx 1\mu m$ required in future high density MR reproduce heads, it is unlikely that H_j will be large enough to cancel H_d at practical maximum allowable current density without t_1 being significantly larger than t_2. Additionally, the exchange pinning strength on film 12 due to film 16 scales as $1/t_2$, and achieving sufficient pinning strength to maintain $\theta_2 \approx 90°$ can require reducing t_2 below minimum thickness requirements on t_1 necessary to avoid saturation of film 10 by signal fields.

b) As taught in US-A-5,159,513, the last deposited pinning layer 16 is an electrical conductor (as is FeMn) so that sense current from the current leads 18,20 deposited atop film 16 could travel down into the SV trilayer. The presence of a conductive pinning layer shunts sense current away from the SV layers, thereby resulting in a loss of output signal from the device.

c) The most common exchange pinning material used to date, FeMn, is well known to be corrosive, and thus long term durability of the disclosed prior art SV head would be a potentially serious problem. The problem is made worse by the fact that in the present case, the FeMn is in the active area of the SV device, where high current densities and associated Joule heating may accelerate the corrosion. Such heating in the active area is also bad in that the pinning strength of an FeMn exchange-coupling layer can decay significantly with increasing temperature. This temperature problem is exacerbated by the possibility of a slow long term re-annealing of the FeMn in the presence of the magnetic field of H_d+H_j at the site of the interface between films 10 and 12 where H_d and H_j are in the same direction, and oppose the pinned magnetization direction of film 12. Such re-annealing would progressively destroy the transverse pinning of film 12 and render the SV device nonfunctional.

d) The intrinsic linear resolution of a SV reproduce head is not sufficient for a high density recording system, and analogously to the conventional AMR head technology, the presence of additional magnetic shielding as part of the total head design will be required. The shields add cost and complexity in fabricating the head, particularly as the shield/sensor gap spacing must be reduced to accommodate future requirements on increasing storage densities.

[0009] US-A-5 287 238 discloses a magnetoresistive read head having a dual spin-valve structure formed of ferromagnetic layers separated by two layers of non-magnetic conductive material. However, like in US-A-5 159 513 the magnetisation of each outer ferromagnetic layer is pinned by either an antiferromagnetic layer or a hand magnetic layer.

[0010] The present invention is aimed at overcoming all four of the limitations of the prior art SV head design described above. A magnetoresistive reproduce head according to the invention is defined in claim 1. This head referred herein as an SV-DMR (spin-valve dual magnetoresistance) device, effectively consists of two SV sensor elements configured such that the two individual SV elements are physically separated by a relatively high resistivity conductive gap spacer. As in a conventional DMR head there is sense current flow through the SV-DMR, and signal generated magnetoresistance changes are detected as head output voltage variations. The SV-DMR eliminates the need for an exchange coupled pinning layer or the mismatch of SV layers to implement the perpendicular biasing arrangement of the prior art. The required perpendicular biasing is attained solely by the interaction between substantially equal thickness magnetic layers of the SV-DMR and the internal magnetic fields arising from the flow of the sense current in the device. The inherent high resolution of the prior art DMR disclosed in US-A-5,084,794 and US-A-5,193,038 is retained in the SV-DMR, and is effectively combined with the high output signal capability provided by the use of SV magnetoresistance elements.

[0011] The invention will be described with respect to the figures, of which:

> Figs. 1a and 1b are drawings of a spin valve magnetoresistive head known in the prior art,
> Fig. 2 is a schematic drawing of the elements of the head of Figs. 1a and 1b illustrating the directions of relevant magnetic fields,
> Figs. 3a and 3b are drawings of a dual magnetoresistive head utilizing spin valve magnetoresistive elements according to the present invention,
> Fig. 4 is a schematic drawing of the dual magnetoresistive head of Figs. 3a and 3b illustrating the directions of relevant magnetic fields, and

[0012] Fig. 5 is graph illustrating the angular bias directions of elements of the dual magnetoresistive head of the invention.

[0013] In the exploded view of the SV-DMR of the invention of Fig. 3, a trilayer comprising the magnetic layer 24, spacer 28, and magnetic layer 26 is deposited on a substrate 22. A conductive gap spacer 30 is then deposited, followed by a second trilayer comprising the magnetic layer 32, spacer 36 and magnetic layer 34.

The layers 24,26,32, 34 are each either single or multiple layer alloys of Co, Fe, and/or Ni, as previously specified for the conventional SVMR, and the spacers 28, 36 are correspondingly either Cu, Ag, or Au. In accordance with the present invention, the thickness and the composition of magnetic layers 24,26 and 32,34 may be substantially the same. The central gap spacer 30 is made of a relatively high resistivity material to limit current shunting from the SV elements, yet provide an electrical path from the current leads 38,40 deposited atop layer 34 (or alternately, atop an additional optional conductive passivation layer) to both SV trilayers. A suitable material for the central gap spacer 30 is TiN, which can provide suitably high resistivity of 100-1000 $\mu\Omega$-cm.

[0014] By consideration of Fig. 4, it may be understood how the SV-DMR simultaneously achieves a close approximation to the ideal perpendicular bias configuration for both SV trilayers without the use of additional pinning layers, and without requiring any thickness mismatch between the magnetic layers of either SV trilayer. It will be first noted that the structure of Fig. 4 is physically symmetrical about a center line through the spacer 30, and resultantly is "antisymmetrical" with respect to the magnetic fields generated by the current J_{total} flowing through the device. In view of this, an explanation of the magnitudes of the fields at the trilayers left of the spacer 30, that is at layers 24,26, is the same as that for the fields at the layers 32,34. (As noted, the antisymmetry affects only the current generated fields' directions, not their magnitudes.) In Fig. 4, the fields acting on each magnetic layer of a trilayer is represented by the field vectors shown directly adjacent to the layer, with the following notational conventions. H_{dx} is the demagnetization field arising from magnetic layer "x", and when shown adjacent to any particular magnetic layer, it acts on that layer. H_{jy} is the current field acting on magnetic layer "y", and arises from the current distribution flowing in all the other magnetic layers.

[0015] Considering the resultant fields at the magnetic layers to the left of the center line of the spacer 30, the current field H_{j24} on the outer layer 24 resulting from the current flowing in the other conducting layers superimpose to maximize the magnitude of H_{j24}. In the case of the inner layer 26, the current fields from current flowing in the majority of layers to the right of layer 26 are partially canceled by that current flowing in those fewer layers to the left of layer 26, so that H_{j24} is nearly three times larger in magnitude than H_{j26}. Further, since layers 24 and 34 are magnetized in opposite directions, the transverse demagnetizing field H_{d24} due to layer 24, at the site of layers 24 or 26, is substantially canceled out by the demagnetization field H_{d34}. With the right choices of parameters, the large asymmetry in current field strength between inner and outer magnetic layers, combined with the substantial reduction in net demagnetizing field, can enable establishment of a quasi-perpendicular bias configuration with the outer layer 24 being effectively pinned transversely because $|H_{j24}| >> |H_{d24}-H_{d34}|$ and the inner layer 26 remaining biased at θ_4 near 0° because H_{j26} is approximately canceled out by the net demagnetization field $|H_{d24}-H_{d34}|$. It will be appreciated that this same explanation is applicable to the magnetic field conditions in the SV-DMR to the right of the center line.

[0016] For the SV-DMR, the magnetoresistive part of p is $\propto \Delta\rho/\rho(\cos(\theta_3-\theta_4)+(\cos(\theta_6-\theta_5)/2$, which in the case $\theta_3 \approx 90$ and $\theta_5 \approx -90$, means that ρ is $\propto \Delta\rho/\rho(\sin\theta_4-\sin\theta_5)/2$. Thus, analogous to the conventional AMR-DMR the SV-DMR output signal measures the difference $(\sin\theta_4-\sin\theta_5)$ in angular rotation between magnetic layers 26 and 32. To the extent that layers 24,34 remain effectively pinned, or saturated at ±90°, the magnetics of the SV-DMR is analogous to that of the AMR-DMR, and the SV-DMR reproduce head will retain the AMR-DMR qualities of performance at high recording densities with large intrinsic linear resolution limited by the size of the gap spacer 30. It will also be noted that the SV-DMR operates in the same manner whether the bias point magnetizations M_4, M_5 of layers 26,32 are parallel as shown in Fig. 4, or antiparallel, since $\sin\theta = \sin(180°-\theta)$.

[0017] Fig. 5 shows the results of a two-dimensional micromagnetic calculation of the detailed bias distribution $\theta(y)$ for a SV-DMR with all magnetic layers chosen to be identical. Parameters include L=1.5µm, magnetic layers 24,26,32,34 of equal thickness equal to 8nm, spacers 28,36 of thickness 3nm, current density $J=1.6 \times 10^7$ amp/cm^2 in either SV element, saturation flux density $B_s=1.2$ KG (= 0.12 T) and anisotropy field $H_k=8$ Oe (≈ 636.6 A/m). The resistivity of the central conducting gap spacer 30 with thickness 60nm is assumed to be chosen so that it shunts 10% of the total sense current. Exchange coupling between magnetic layers across the thin conductors 28,36 is assumed to be zero. As seen in graph 40, the $|\theta_4$ or $\theta_5| \leq 20°$ with mean values near 0. Similarly, as seen in graph 42, the outer magnetic layers 24,34 are pinned (that is, well saturated) with $|\theta_3$ or $\theta_6| \approx 90°$ over the central half of the element height, L. The non uniformities over the element height are unavoidable consequences of the non-uniformity in the demagnetizing fields near the element edges, but do not interfere with the essential operation of the SV-DMR as described.

[0018] The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope of the invention as defined by the appended claims.

Claims

1. A magnetoresistive reproduce head comprising:

   a) a substrate (22)
   b) a multilayered structure deposited on the substrate (22), the structure further comprising

a first trilayer having first and second ferromagnetic layers (24),(26), the first ferromagnetic layer (24) separated from the second ferromagnetic layer (26) by a first conductive non-magnetic layer (28) having a first thickness, a second trilayer having third and fourth ferromagnetic layers (32),(34), the third ferromagnetic layer (32) separated from the fourth ferromagnetic layer (34) by a second conductive non-magnetic layer (36) having a second thickness, the first and the second trilayers sandwiching a central conductive non-magnetic spacer (30) of a third thickness,

c) means (38),(40) for producing a current flow through the magnetoresistive reproduce head, wherein the magnetic fields generated by the current flow magnetizes the first ferromagnetic layer (24), the second ferromagnetic layer (26), the third ferromagnetic layer (32) and the fourth ferromagnetic layer (34) such that the first and the fourth magnetic layers (24),(34) are fixedly magnetized substantially antiparallel to each other, the first and the second ferromagnetic layers (24),(26) are magnetized substantially perpendicular to each other, the third and the fourth ferromagnetic layers (32),(34) are magnetized substantially perpendicular to each other, all of said magnetisations being in planes substantially parallel to the planes of said layers, and

d) means for sensing the variations of resistivity of the magnetoresistive head in response to an applied magnetic field.

2. The magnetoresistive head of Claim 1 wherein the first and the fourth ferromagnetic layers (24),(34) are substantially identical in magnetic and electrical properties, and the second and the third ferromagnetic layers (26),(32) are substantially identical in magnetic and electrical properties.

3. The magnetoresistive head of Claim 1 wherein the ferromagnetic layers (24),(26),(32),(34) are layers fabricated from the group consisting of Co, Fe, Ni.

4. The magnetoresistive head of Claim 3 wherein the first and the second conductive layers (28), (36) are fabricated from the group Au, Ag, Cu.

5. The magnetoresistive head of Claim 1 wherein the first (24), the second (26), the third (34), the fourth (34) ferromagnetic layers are of equal thickness.

6. The magnetoresistive head of Claim 1 wherein the first and the second conductive layers (28), (36) are of thicknesses less than the thickness of the ferromagnetic layers (24),(26),(32),(34).

7. The magnetoresistive head of Claim 1 wherein the conductive spacer (30) has a high resistivity relative to that of the first and second trilayers.

8. The magnetoresistive head according to any preceding claim, wherein said magnetoresistive head being arranged in a magnetoresistive head assembly for detecting magnetically recorded signals having a characteristic recorded minimum bit length, wherein the thickness of the central conductive non-magnetic spacer (30) is substantially equal to said characteristic minimum bit length, and said means for sensing the variations of resistivity of the magnetoresistive head are responsive to the magnetically recorded signals.

Patentansprüche

1. Magnetoresistiver Wiedergabekopf mit

a) einem Substrat (22),

b) einer auf dem Substrat (22) liegenden, mehrschichtigen Struktur, die einen ersten Dreischichtverbund mit einer ersten und zweiten ferromagnetischen Schicht (24, 26), welche durch eine erste leiffähige, nichtmagnetische Schicht (28) mit einer ersten Dicke voneinander getrennt sind, und einen zweiten Dreischichtverbund mit einer dritten und vierten ferromagnetischen Schicht (32, 34) aufweist, welche durch eine zweite leiffähige, nichtmagnetische Schicht (36) mit einer zweiten Dicke voneinander getrennt sind, wobei zwischen dem ersten und zweiten Dreischichtverbund eine zentrale leiffähige, nichtmagnetische Trennschicht (30) einer dritten Dicke eingeschlossen ist,

c) Mitteln (38, 40) zum Erzeugen eines Stromflusses durch den magnetoressistiven Wiedergabekopf, wobei die durch den Stromfluß erzeugten Magneffelder die erste ferromagnetische Schicht (24), die zweite ferromagnetische Schicht (26), die dritte ferromagnetische Schicht (32) und die vierte ferromagnetische Schicht (34) magnetisieren, so daß die erste und vierte Magnetschicht (24, 34) im wesentlichen antiparallel zueinander, die erste und zweite ferromagnetische Schicht (24, 26) im wesentlichen senkrecht zueinander, und die dritte und vierte ferromagnetische Schicht (32, 34) im wesentlichen senkrecht zueinander magnetisiert werden, wobei alle Magnetisierungen in Ebenen stattfinden, die im wesentlichen parallel zu den Ebenen der Schichten liegen, und

d) einem Mittel zum Abtasten der Resistivitätsveränderungen des magnetoresistiven Wiedergabekopfes in Abhängigkeit vom angelegten Magneffeld.

2. Magnetoresistiver Wiedergabekopf nach Anspruch 1, dadurch gekennzeichnet, daß die erste und vierte ferromagnetische Schicht (24, 34) bezüglich magnetischer und elektrischer Eigenschaften im wesentlichen identisch sind und die zweite und dritte ferromagnetische Schicht (26, 32) bezüglich magnetischer und elektrischer Eigenschaften im wesentlichen identisch sind.

3. Magnetoresitiver Wiedergabekopf nach Anspruch 1, dadurch gekennzeichnet, daß die ferromagnetischen Schichten (24, 26, 32, 34) aus der aus Co, Fe und Ni bestehenden Gruppe hergestellt sind.

4. Magnetoresistiver Wiedergabekopf nach Anspruch 3, dadurch gekennzeichnet, daß die erste und zweite leiffähige Schicht (28, 36) aus der Gruppe Au, Ag, Cu hergestellt sind.

5. Magnetoresistiver Wiedergabekopf nach Anspruch 1, dadurch gekennzeichnet, daß die erste (24), zweite (26), dritte (34) und vierte (34) ferromagnetische Schicht von gleicher Dicke sind.

6. Magnetoresistiver Wiedergabekopf nach Anspruch 1, dadurch gekennzeichnet, daß die erste und zweite leiffähige Schicht (28, 36) eine Dicke aufweist, die geringer als die Dicke der ferromagnetischen Schichten (24, 26, 32, 34) ist.

7. Magnetoresistiver Wiedergabekopf nach Anspruch 1, dadurch gekennzeichnet, daß die leiffähige Trennschicht (30) einen, gegenüber dem des ersten und zweiten Dreischichtverbunds, hohen Widerstand aufweist.

8. Magnetoresistiver Wiedergabekopf nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß der magnetoresistive Wiedergabekopf in einem magnetoresitiven Wiedergabekopfträger zum Erfassen magnetisch aufgezeichneter Signale angeordnet ist, welche eine charakteristische, aufgezeichnete Mindestbitlänge aufweisen, daß die Dicke der zentralen leiffähigen, nichtmagnetischen Trennschicht (30) im wesentlichen der charakteristischen Mindestbitlänge entspricht, und daß die Mittel zum Abtasten der Resistivitätsveränderungen des magnetoresistiven Wiedergabekopfes auf die magnetisch aufgezeichneten Signale ansprechen.

Revendications

1. Tête de reproduction magnétorésistive comprenant :

   a) un substrat (22)

   b) une structure multicouches déposée sur le substrat (22), la structure comprenant en outre un premier système à trois couches ayant des première et seconde couches ferromagnétiques (24, 26), la première couche ferromagnétique (24) étant séparée de la seconde couche ferromagnétique (26) par une première couche non magnétique conductrice (28) présentant une première épaisseur, un second système à trois couches comportant des troisième et quatrième couches ferromagnétiques (32), (34), la troisième couche ferromagnétique (32) étant séparée de la quatrième couche ferromagnétique (34) par une seconde couche non magnétique conductrice (36) présentant une seconde épaisseur, les premier et second systèmes à trois couches prenant en sandwich une couche de séparation non magnétique conductrice centrale (30) d'une troisième épaisseur,

   c) un moyen (38), (40) pour produire une circulation de courant à travers la tête de reproduction magnétorésistive, dans laquelle les champs magnétiques générés par la circulation du courant magnétisent la première couche ferromagnétique (24), la seconde couche ferromagnétique (26), la troisième couche ferromagnétique (32) et la quatrième couche ferromagnétique (34) d'une manière telle que les première et quatrième couches ferromagnétiques (24, 34) sont magnétisées de manière fixe sensiblement anti-parallèles l'une à l'autre, les première et seconde couches ferromagnétiques (24), (26) sont magnétisées sensiblement perpendiculaire l'une à l'autre, les troisième et quatrième couches ferromagnétiques (32), (34) sont magnétisées sensiblement perpendiculaires l'une à l'autre, toute lesdites magnétisations étant dans des plans sensiblement parallèles aux plans desdites couches, et

   d) un moyen pour détecter les variations de résistivité de la tête magnétorésistive en réponse à un champ magnétique appliqué.

2. Tête magnétorésistive selon la revendication 1, dans laquelle les première et quatrième couches ferromagnétiques (24), (34) sont sensiblement identiques en propriétés magnétiques et électriques et les seconde et troisième couches ferromagnétiques (26), (32) sont sensiblement identiques en propriétés magnétiques et électriques.

3. Tête magnétorésistive selon la revendication 1, dans laquelle les couches ferromagnétiques (24), (26), (32), (34) sont des couches fabriquées à partir du groupe qui est constitué de Co, Fe, Ni.

4. Tête magnétorésistive selon la revendication 3, dans laquelle les première et seconde couches

conductrices (28), (36) sont fabriquées à partir du groupe qui est constitué de Au, Ag, Cu.

5. Tête magnétorésistive selon la revendication 1, dans laquelle la première (24), la seconde (26), la troisième (32), la quatrième (34) couches ferromagnétiques sont d'une épaisseur identique.

6. Tête magnétorésistive selon la revendication 1, dans laquelle les première et seconde couches conductrices (28), (36) sont d'une épaisseur inférieure à l'épaisseur des couches ferromagnétiques (24), (26), (32), (34).

7. Tête magnétorésistive selon la revendication 1, dans laquelle la couche de séparation conductrice (30) a une résistivité élevée par rapport à celle des premier et second systèmes à trois couches.

8. Tête magnétorésistive selon l'une quelconque des revendications précédentes, dans laquelle ladite tête magnétorésistive est disposée dans un ensemble de têtes magnétorésistif pour détecter des signaux magnétiquement enregistrés ayant une longueur de bit minimale enregistrée caractéristique, dans laquelle l'épaisseur de la couche de séparation non magnétique conductrice centrale (30) est sensiblement égale à ladite longueur de bit minimale caractéristique et lesdits moyens pour détecter les variations de résistivité de la tête magnétorésistive sont sensibles aux signaux magnétiquement enregistrés.

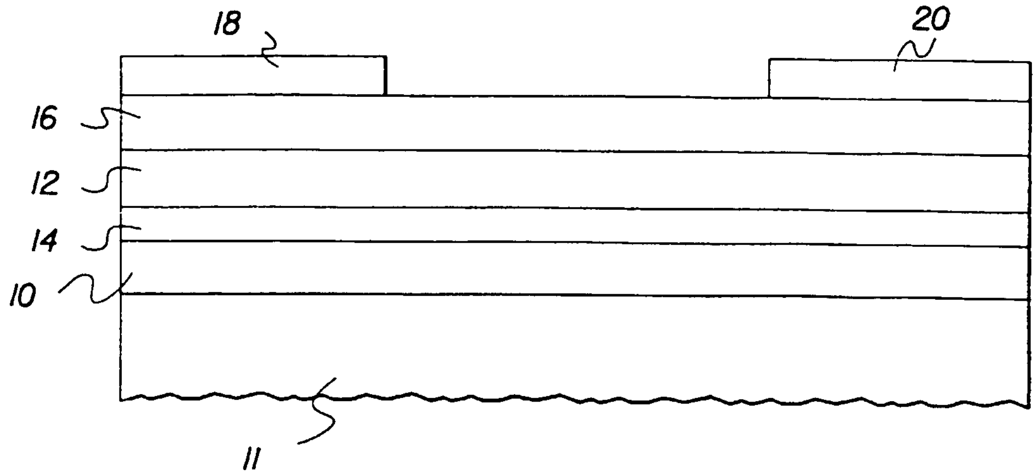

FIG.1a
(PRIOR ART)

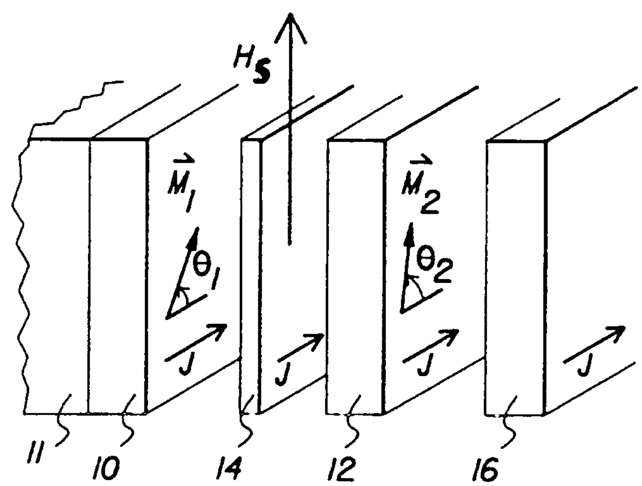

FIG.1b
(PRIOR ART)

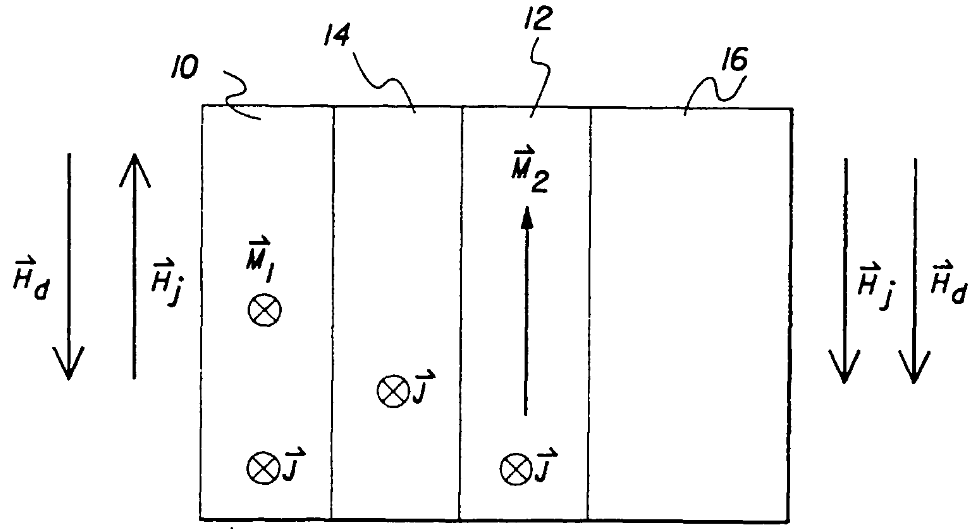

FIG. 2
(PRIOR ART)

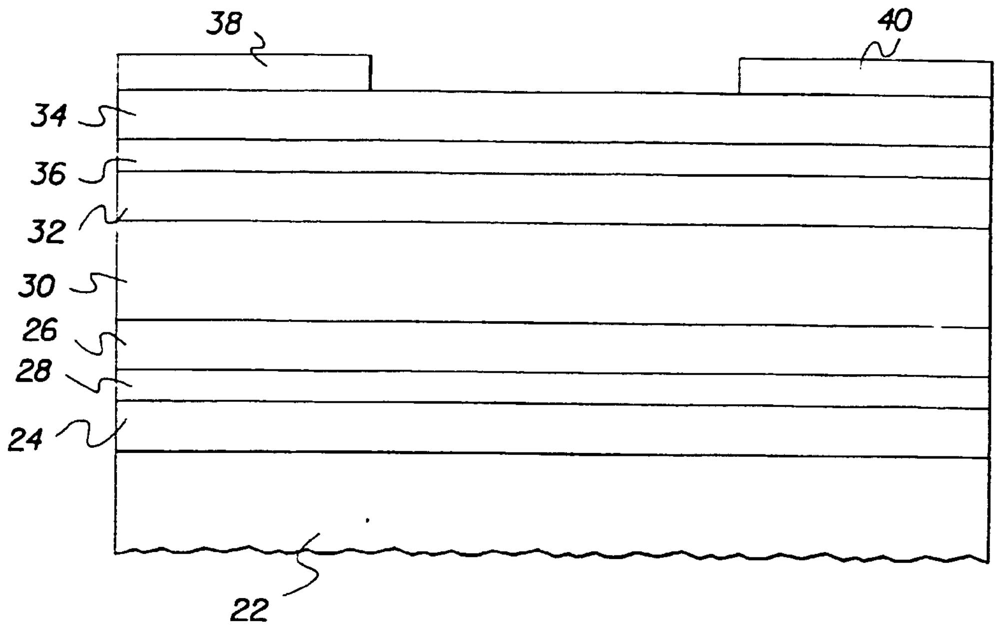
38
40
34
36
32
30
26
28
24
22

FIG. 3a

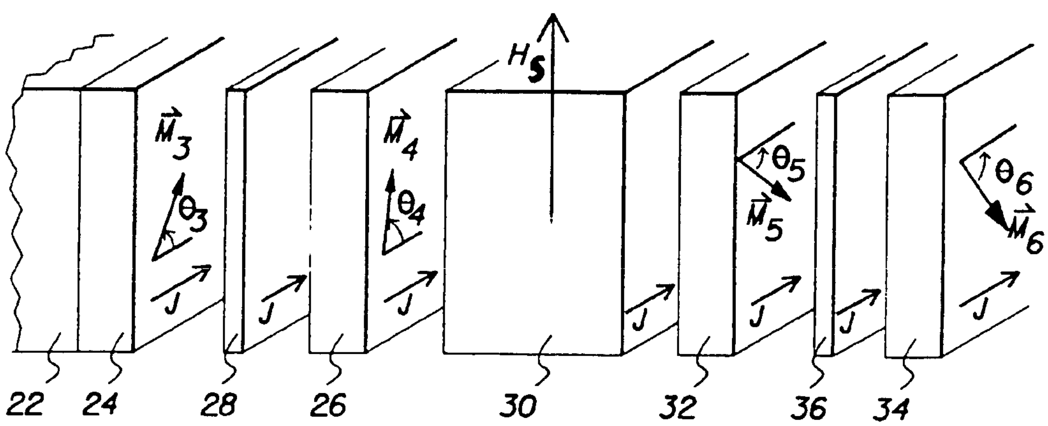
H_S
$\vec{M}_3$
θ_3
$\vec{M}_4$
θ_4
θ_5
$\vec{M}_5$
θ_6
$\vec{M}_6$
J
22
24
28
26
30
32
36
34

FIG. 3b

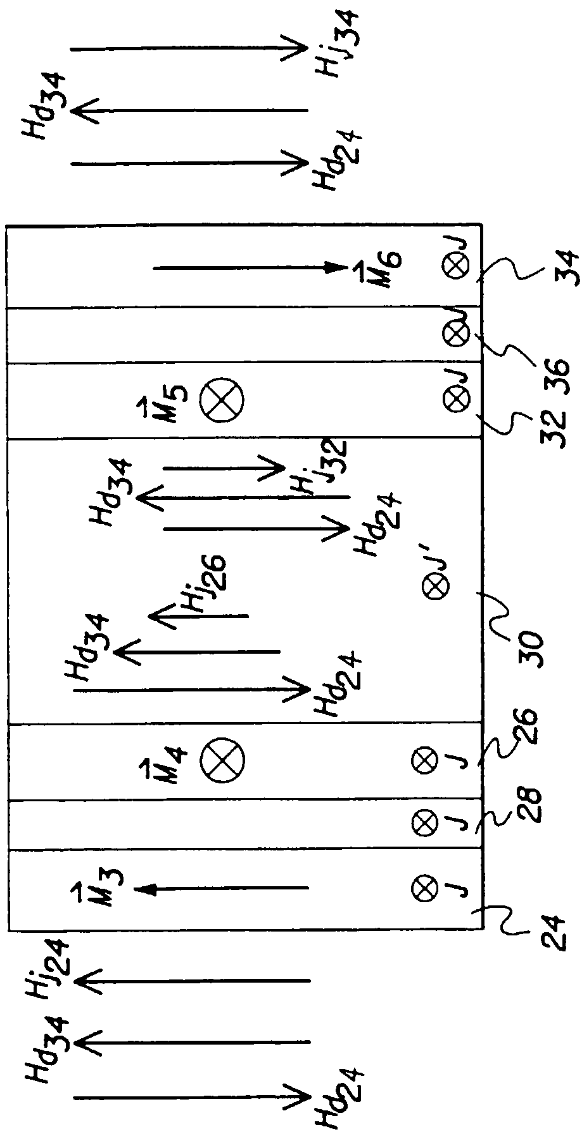
Hj34
Hd34
Hd24
M6
J
34
36
32
M5
Hd34
Hj32
Hd24
J'
30
Hj26
Hd34
Hd24
26
M4
28
M3
24
Hj24
Hd34
Hd24

FIG. 4

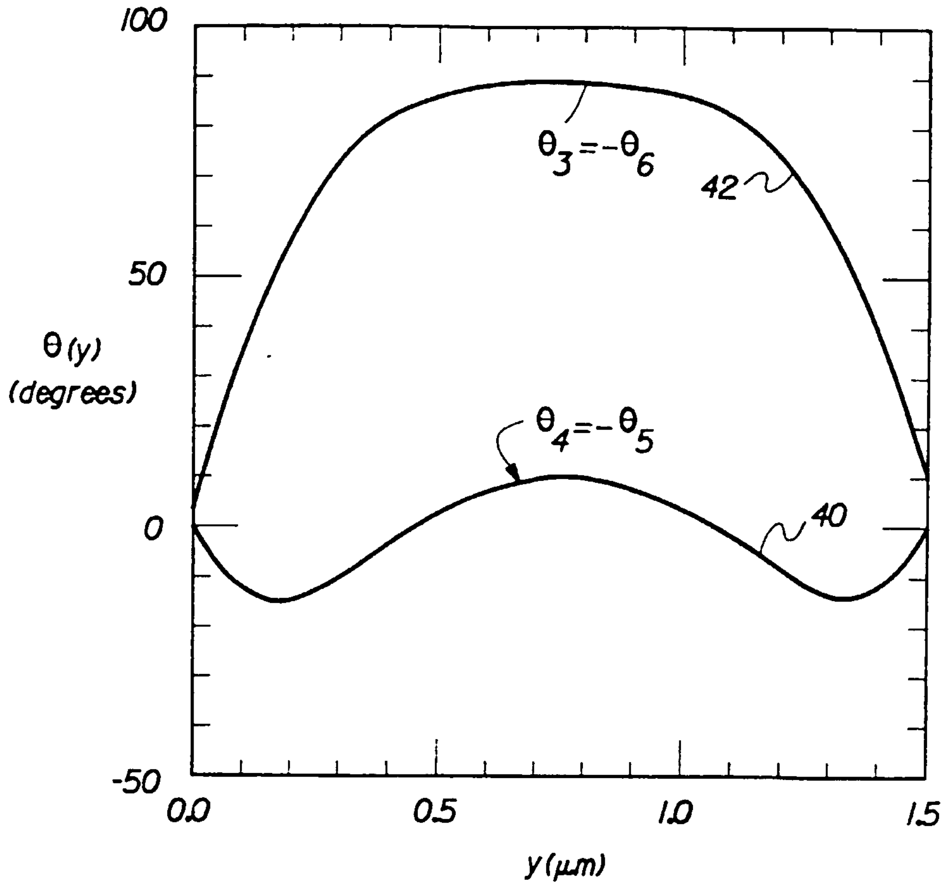

FIG. 5